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CONTROL OF BARK-BEETLE INFESTATION IN LODGEPOLE PINE

(Prepared at request of Forest Supervisor of the Nebraska National Forest for use as a lesson in a correspondence course by the Denver office.)

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The control of injurious forest insects can be approached from three different angles: direct or mechanical control, indirect or silvicultural control, and biological control. Though these are distinct means of control, it is often necessary to utilize two or all of them in the solution of some insect problems.

Direct or mechanical control refers to such methods as peeling or burning of infested trees, the use of insecticides in spraying, dusting, fumigating, and trapping. In brief, artificial methods of control are applied directly to the insect.

Indirect or silvicultural methods of control are directed toward the prevention of insect epidemics. Such methods are found in the management of forests so that conditions adverse to the development of insect epidemics are maintained.

Biological methods of control call for the utilization of all beneficial biotic factors, such as parasites and predators. Though the possibilities in this field are unlimited, there are many difficulties which often make their use impractical.

In the western United States forest-insect control is primarily a problem of protecting mature timber stands from the ravages of insects by the use of direct control measures. In the eastern United States,

where the forests are rapidly becoming a matter of second-growth stands, entomology and management are more closely related, with indirect, or silvicultural methods of control being sought. Such a condition will gradually take place in the utilizable forests of the West, as virgin forests are replaced by intensively managed second-growth stands.

In addition to these phases of control, there are climatic factors such as temperature, winds, and rainfall which have a distinct bearing upon forest-insect problems. Though no influence can be exercised over such factors, advantage can be taken of any "breaks" which they may offer.

The purpose of this lesson is to discuss the different phases of direct control of bark beetles in lodgepole pine.

DIRECT CONTROL OF BARK BEETLES INFESTING LODGEPOLE PINE

In considering the control of bark beetles which attack and destroy lodgepole pine, it must be remembered that once a tree has been successfully attacked its life can not be preserved. As an attack is considered successful when the resistance of the tree is overcome, control measures are directed towards the destruction of the insect broods, to prevent their subsequent emergence and attack of other trees, with no consideration given to the tree. Bark-beetle broods can be destroyed by several methods of artificial control, the method and time of application varying for different regions and environmental conditions encountered. Though outbreaks of these insects can be reduced, the insects can not be exterminated, so control measures must not be

considered as a panacea or cure-all for all time. The results of a bark-beetle project may last for years, or they may be of extremely short duration.

In justifying the expense of bark-beetle control, such factors as the value and merchantability of the timber, destruction of forest cover in its relation to watershed protection, creation of fire hazard, and the danger of the epidemic spreading into more valuable timber stands must be considered. The proper evaluation of these factors, balanced against the cost of the operation, will determine the economics of the project. However, it is difficult to determine the extent of the depredations or the course the epidemic will take if no control is instituted. Following a control operation it is often necessary to estimate the benefits of the operation. Control meesures instituted during the decline of an outbreak would tend to place an inflated value upon the results secured. On the other hand, control instituted during the time an outbreak was building to an epidemic would show opposite results, giving the project the appearance of a failure, though in reality a greater saving of timber would be made.

The actual effects of control can not be determined from a comparison of the outbreak at the time of control and the amount of next season's infestation. In explanation, let it be assumed that control is conducted against an infestation of 10,000 trees, of which 80%, or 8,000 of them, are treated. If this infestation were increasing at the rate of 1 to 4, or 400%, there would be 8,000 trees infested from the 2,000 left during the control operation. From a comparison of the

losses during the two years it would appear that control had reduced the infestation by only 20%, or a saving of 2,000 trees. However, as there would have been 40,000 trees attacked had no control been instituted, the reduction was actually 80%, or a saving of 32,000 trees. Under opposite conditions had control been conducted during a decline in the infestation of 2-1, or 50%, there would have been only 1,000 trees infested the following year from the 2,000 trees which had been left untreated. A comparison of the two years losses would indicate a reduction of 90% and a saving of 9,000 trees. This is an inflated figure, as there would have been only 5,000 trees infested had no control been instituted; the actual effects of control would still remain the same as the percent treated, or 80%, and a saving of 4,000 trees. So though the reduction in the subsequent infestation is in direct proportion to the percentage treated, a greater volume of timber will be saved following the direction of control against increasing infestations.

It is difficult to foresee accurately the course which an outbreak of destructive forest insects is going to follow. From an intensive study of brood conditions during a bark-beetle outbreak, the future of the epidemic can be forecasted to a limited degree. However, as at this time such forecasts are complicated and questionable, one is left with the task of basing the future upon what has occurred in the past. One may take the average loss within an area over a period of years, or a comparison of the past few years' loss, or the extent of the depredation in adjacent untreated areas, as a basis for determining

the results which have been or will be secured from control.

In considering the prevention or control of bark-beetle outbreaks in lodgepole pine, there are a few general rules which should always receive proper consideration:

1. - A general knowledge of the status of bark-beetle infestation in the lodgepole pine stands of all adjacent forests should be available. This information can be secured by a "red-top" survey, which indicates the presence or absence of destructive beetles. Such a survey should be made annually, and considered as a separate project, not to be made in association with other work. When "red-tops" reveal an abnormal condition, a more intensive survey should be made.
2. - Prompt and thorough control of all potential outbreaks. Thorough control means the treatment of as near 100 percent of the infested trees as is feasible within physical limits.
3. - All infested trees within the infested area should be treated the first year of the operation, and followed by annual maintenance control for as long as is necessary.
4. - No project should be undertaken without accurate knowledge of conditions in all of the surrounding watersheds.
5. - Control measures should not be instituted against rapidly declining outbreaks.
6. - Though control measures can be conducted against summer generations of bark beetles which have two or more generations annually, the most effective results are obtained when directed against overwintering broods. Such operations can be conducted in the fall following the last attack or in the spring prior to emergence.

MECHANICS OF BARK-BEETLE CONTROL

In the institution of artificial control measures for the prevention or suppression of a bark-beetle epidemic in stands of lodgepole pine, there are three major steps, which are: preliminary surveys, spotting and marking of infested trees for treatment, and the actual treatment. None of these steps should be slighted, as they all have a direct bearing upon the ultimate success of all control projects. A preliminary survey of the area in question, as well as of all adjacent areas, is essential in determining the status of the infestation, which in turn determines the necessity and feasibility of instituting control as well as the funds required, and permits proper administrative planning. The importance of spotting or marking of infested trees for treatment should require no explanation. It is unquestionably the most important phase of all actual control operations, and the success of the project is largely dependent upon its efficiency. All infested trees must be located and marked for treatment; trees which do not require treatment (pitched-out, abandoned, etc.) must not be marked; and accurate maps showing the location of all marked trees must be prepared for the treating-crew foremen if spotting is to be considered as being efficiently conducted. In treating, all of the marked trees must be re-located and properly treated. When these phases of control are thoroughly performed, success will follow the effort.

Preliminary or Extensive Bark-Beetle Surveys

The status of a bark-beetle infestation can only be determined from an extensive survey, which will vary in intensity with the size of the area and the character of the infestation. With small units it is often possible to survey a large percent of the area. With large areas the necessary data can only be secured from samples which are indicative of conditions within the entire unit. The accuracy of such surveys depends upon the fairness of the samples selected and the accuracy of the acreage figures to which the data from the samples are to be applied. Extensive surveys can not be expected to record the exact number of infested trees for each small drainage, but when the data are applied to a larger unit the errors are compensated and the total figures are sufficiently accurate.

In conducting insect surveys the use of sample strips has proved more efficient than sample plots. Though these two systems are perhaps equal in accuracy, strips are easier to operate and permit the coverage of a much larger acreage.

Location of Sample Strip:

Sample strips must be located so that the data secured will be a fair sample of the area under consideration. Though selecting the location and direction that strips are to be extended is not a difficult task, the best judgment of the officer in charge of the survey must always be used. It is evident that strips along creek bottoms or the tops of ridges are not indicative of average conditions. To be accurate,

strips must sample all different types within an area, such as non-host timber, sagebrush, openings, and areas of reproduction, in proportion to the percentage of the total area they represent. Strip lines must always be projected on a general compass bearing so that the cruiser will know where he is expected to go, and to insure the traversing of such nonproductive areas as sagebrush flats, reproduction, and rock slides. In covering an area, strip lines assume a different pattern, depending upon the size and shape of the unit as well as the nature of the terrain.

With large, fairly solid bodies of timber of a known acreage, strips are merely located so as to secure samples from all portions of the area. However, when small patches of timber are encountered with the distance between them so great as to prohibit the inclusion of the entire acreage in the survey, the task is not so easy. With such areas it is necessary to confine the strip to the timbered acreage of each small tract, or at best to a group of two or more which are closely connected. May it again be stated that strip location must always receive the careful consideration of the officer making the selection. Such careful thought can not be supplanted by prescribed regulations, as each area presents an individual problem. There are, however, a few rules one should bear in mind, as they are applicable for all areas:

1. - Strip lines must not be projected along trails, ridges, or streams.
2. - Strip lines must be projected perpendicular to the course of the main drainage being covered, as such locations provide a sample of different elevations, exposures, and timber types. This rule can not be followed in connection with small side streams or draws

associated with the main drainage.

3. - Strip may follow section lines if such compass bearing gives the desired sample.

4. - Strip can extend from a selected starting point in cardinal directions or angles, as the terrain and area may demand. The direction of the strip should be selected and plotted upon the cruiser's map prior to the start of each day's work, and only under very unforeseen conditions should departures be made from it.

5. - Strip should be planned so as to eliminate long walks to starting points or back to camp at the close of each day's work. They can be extended in any geometric pattern, suited to the requirements of the area, that will provide a fair sample and return the cruiser to the starting point or to some place where he can be met with transportation.

6. - Where impassable swamps, lakes, rock slides and cliffs are encountered, offsets can be made so as to return to the original course. In making such offsets, only the distance parallel to the general course being followed should be recorded as the distance traveled, and all infested trees encountered on the offset must be disregarded, as it is evident that none would have been encountered on the original course.

Width of Sample Strip:

The most effective width of strip is one which permits the cruiser to follow a center line and spot infested trees with a minimum amount of

travel. It has been found that in lodgepole pine and white pine types a one-chain strip is all that one man can effectively examine. In more open forest types a wider strip can often be used.

Compass Lines:

Though strips are projected on compass bearings for the purpose of keeping the cruiser upon a prescribed course, it is not necessary to follow the bearing with extreme accuracy. Long compass shots, or utilizing the angle of shadows from tree trunks, or keeping the sun in a definite position will speed up the work and be sufficiently accurate. A staff compass is not necessary for such surveys, and their use is not recommended. A 2½- or 3-inch-needle hand compass is faster and sufficiently accurate. When too much attention is given to the accuracy of the compass line, infested trees are missed, which often makes a material difference in the final data.

Operation or Mechanics of Running Strip:

In lodgepole pine the best results are secured by each cruiser working alone. The cruiser extends his strip along the prescribed compass line, paces the distance, and counts the infested trees on a strip one chain in width. It is necessary that the distance traveled on strip be measured by pacing in order to compute the actual acres covered in the sample surveyed. The newly infested trees counted on the strip are reduced to number of trees per strip acre, which figure is then applied to the entire acreage of the area under consideration. If surveys of this character are to be reliable, both the strip data and the acreage

of the area to which they are to be applied must be carefully secured.

Percent of Area to be Covered by Survey:

No definite rule can be given as to the percentage of an infested area which should be covered during extensive insect surveys. Small areas require a greater percentage than large ones, and light infestations more than heavy infestations. With small units varying from fifty to several hundred acres, from 8 to 15 percent of the area must be included in the sample to secure accuracy. Large units involving thousands of acres do not require such a large percentage, as the sample secured is larger and represents a greater variation of types. In surveying large areas of lodgepole pine, the minimum size of the sample should not be less than 1½ percent of the total acreage.

Identification of Insect-Infested Trees:

Trees infested with bark beetles can be recognized by the presence of small pitch exudations (pitch tubes) which form at the mouth of the entrance hole, or by the boring dust at the base of the tree or on flakes of bark. The presence of pitch tubes is not an infallible rule, for when the attack is extremely heavy there are very few, if any, to be seen. The vitality or resistance of the tree to insect attack has a bearing upon the presence of pitch tubes. Large pitch tubes are usually, though not always, an indication of pitched-out attacks, indicating that the insects were unable to overcome the resistance of the tree. Fresh woodpecker work is a true indication that there were and possibly are insects beneath the bark. However, it does not prove that the insect is the species against which control measures are being instituted.

As the mountain pine beetle and Black Hills beetle are the two most important enemies of lodgepole pine, most projects will be directed against these two species. In surveying areas for the presence of these beetles, cruisers are often called upon to distinguish between the work of these two species and that of various species of Ips, Pityogenes, etc. The best plan to follow is to thoroughly familiarize oneself with the characteristic gallery pattern of the Dendroctonus species, and to disregard all others. A point to be remembered is that the egg galleries or main channels of Dendroctonus beetles are always packed solid with boring dust, except for an inch or two at the upper end, while with the secondary species the galleries, which are nearly always forked, are kept open.

Though the foliage of some trees begins to fade within a few weeks after attack, this condition can only be used as a guide to infested groups, as the foliage on most lodgepole remains green until the spring following attack.

Reporting on Insect-Survey Data:

Several methods can be employed in presenting survey data, but the one preferred is a discussion of each unit or area, followed by a consolidated table of data from all units. Though the manner of presenting will vary with the ideas of the reporting officer, there are certain data which should always be shown regardless of what other information may be included. These data, which are secured from the strip survey, will permit one who is not familiar with the area to

visualize the situation and allow comparisons with other units or forests. These data are as follows:

1. - Total acreage of the area or unit to which the survey data are to be applied.

2. - Acres of sample strip or miles of strip of a stated width. With these data and the total acreage of the area, the percent covered can be determined, though this information can be included in the table if desired.

3. - Number of infested trees counted on strip, or the average number of infested trees per acre of strip. The latter gives the best idea as to the intensity of the infestation, and is secured by dividing the total number of infested trees counted by the total number of acres covered. If desired, both the above items could be shown.

4. - Total number of infested trees in the area or unit under consideration. Secured by multiplying the total acreage of the area by the average number of infested trees per acre.

5. - To show the results of control, or the increase or decrease of the infestation, the status of the outbreak from the previous season's survey should be shown when such data are available. When control measures were conducted the previous season, the number of trees treated is essential information. It is not advisable to attempt to count both "red-tops" and newly attacked trees while running strip, as errors are bound to occur. When areas are being surveyed for the first time, data for the previous

season are dispensed with, and the status of the existing infestation becomes the deciding factor in determining the need for control.

6. - A small scale map with the general location of the infested areas marked in colors with suitable legends should accompany the report.

7. - The reporting officer's reaction to the advisability of instituting control is always of value. The "hot-spots" of the area should be mentioned, as well as those portions of the total area which could be eliminated owing to light infestations.

Spotting or Locating of Infested Trees for Treatment

The most important step of all actual control projects is the proper and thorough location of all infested trees for subsequent treatment. This can best be accomplished by a systematic, 100-percent survey of the area to be treated, using a spotting crew of three or six men. With small areas of 10 to 100 acres, this survey can often be conducted by one experienced man, who examines all trees for the presence of insects. With a three-man crew the compassman, who is usually the Chief of Party, runs an accurate compass line, paces distances traveled, records data relative to trees marked for treatment, constructs a map showing their location, and assists spotters in the proper selection of trees for treatment. The two spotters cover strip on the side of and parallel to the course of the compassman. With a six-man crew there are two spotters on each side of the compassman, and the Chief of Party follows behind the crew, working from side to side to assist in the proper marking

and to prevent the missing of trees. Regardless of the organization, the chief spotter is always responsible for the character of the work conducted by his crew.

The width of strip that can be covered by each spotter will vary with the timber type and topography. In the usual lodgepole pine forest it has been found that one chain is all that one man can efficiently cover, as it is necessary to actually look at the base of each tree. Each spotter is responsible for the location and proper marking of all infested trees within the boundaries of his strip. When large groups of infested trees are encountered, all spotters assist in marking all trees within the group even though it extends into the next course. The spotter who has the outside strip of the course should always be on the inside during the return, as he is familiar with the boundaries of the previous course.

In surveyed territory it is often expedient to conduct the spotting by sections. With unsurveyed territory, strips are run from base lines along trails, streams or ridges, or it may be necessary to establish a line through the area to be covered. All control projects vary in some detail, and present problems that will need be solved as they are encountered.

Trees selected for treatment are marked in different ways, varying from a blaze to a cloth or card tag tacked upon the tree. When tags are used, it is a good plan to blaze and number the tree on the opposite side, which will permit the re-location of the tree for treatment when the tags are destroyed. The data placed upon the tags will vary for

each project, but regardless of what information is required the serial number of the tree must be shown. These numbers permit a check upon the trees treated, and assure the treatment of all trees spotted. During the treating operation the tags from the treated trees are turned over to the camp manager at the close of each day's work, and are checked against the numbers of the trees marked within the area.

Care must be exercised in the preparation of spotters' maps, as they are used by the treating crew foremen to re-locate trees for treatment. Individual trees are shown by a small dot with the tree number to one side. Groups are indicated by a small circle with the tree numbers (160-192) to the side. Neat and accurate maps are of great assistance to treating-crew foremen, and add to the efficiency of the project.

There is no infallible rule that can be given for the proper marking of infested trees from external evidence. The rules which have been listed will locate trees that have been attacked by bark beetles, but the decision as to the need for treatment must rest with the spotter. It is necessary to examine all insect-attacked trees by removing a piece of bark. Bark should not be removed, nor should spotters chop into or blaze trees unless they are insect-attacked. If by removing the bark it is found that the tree was killed by the insect being combated, and if there are living insect broods beneath the bark, then it is evident that the tree should be marked for treatment. Care must be used in determining if the insects are the brood, larvae, pupae or adults of the species for which control is intended. Parent adults will be found at the top of the egg gallery. Though these adults may be alive at the time of examination,

the tree should not be marked on the strength of their presence alone. In the marking of trees for treatment the best judgment of the spotters must be called upon. To equip themselves for this task they should be familiar with the seasonal history and the work of the insect being combated. Though one can soon learn to distinguish the work of these beetles, trees should not be marked for treatment unless the broods of the insect are beneath the bark. A description of the most important bark-beetle enemies of lodgepole follows later in this lesson.

Treatment of Lodgepole Pine Infested with Bark Beetles

Of the different species of bark beetles which attack and destroy lodgepole pine, the mountain pine beetle (Dendroctonus monticolae Hopk.) and the Black Hills beetle (Dendroctonus ponderosae Hopk.) are of the greatest economic importance. The control methods which are discussed in the following pages are directed primarily against these two insects, though they could be used with equal efficiency against other species.

As has been stated, in developing a method of control for tree-killing species of bark beetles it is impossible to preserve the infested trees if the attacks have been successful. With some trees the attack is unsuccessful and the insects are pitched out; with others only one side may be successfully attacked and killed, which will permit the tree to live for years. However, in the planning of control, these unsuccessful attacks are disregarded, and methods directed towards the destruction of the insect brood within infested trees to prevent its subsequent development, emergence, and attack of additional trees. This requirement demands direct methods of control, which will result in the actual

destruction of the developing insects regardless of their effect on the infested tree. This can be accomplished by the use of fire, removal of the bark while insects are in an immature larval or first-pupal stage, and by exposing the infested logs to the direct rays of the sun when air temperatures are at 85 to 95 degrees. Many other methods have been given experimental tests, some of which though expensive in their application show some promise of success.

In the practice of forestry the cost of applying a selected method of control is an important consideration. This factor very largely determines the method of treatment which is adopted for common practice. There are, of course, such environmental conditions as terrain, timber type, fire hazard, intensity of infestation, etc., which determine the character of treatment to be applied, and with some projects requiring two or more methods. The cost of treatment is influenced by such factors as transportation, availability of trained labor, supervision, and the size of the project.

A burning method of control was successfully practiced in the Big Hole Basin project, Beaverhead National Forest, from 1926 to 1928 inclusive, at which time the treating crews averaged from 7-10 trees per effective man-day. This method of treatment called for the felling of the infested trees, and the decking of the infested logs for subsequent burning. Though during this project horses were used in decking the infested logs, hand logging could be practiced with small infestations, or in areas which are inaccessible to horses. In addition to destroying the insects this method has the added advantage of cleaning up the infested trees.

In the treatment of beetle-infested lodgepole the most effective and economical method of control which is now practiced is the use of an inflammable oil sprayed upon the bole of infested trees for immediate burning. The oil giving the best results is a light fuel oil (Flashpoint 160°, Specific Gravity 32), which in tank-car lots can be purchased for a few cents per gallon.

The equipment used consists of a compressed air sprayer of four-gallon capacity, equipped with carrying strap, oil-resistant hose connected to a hand-lever shut-off, and a specially adapted nozzle having an aperture the size of a #55 drill (.052 inches). Careful experiments have demonstrated that this size and form of nozzle gives the best results. In timber where the infested portion of the bole is more than 20 feet high, it is necessary to use steel extensions, which are made in three-foot lengths. By coupling three of these extensions together the oil may be thrown to a point thirty feet or more in height.

The tanks are filled about three fourths full of oil and pumped to a moderate pressure, high pressure causing the oil stream to break. A few tests will give the burner the feel of the pump when the most effective pressure is obtained, which is about 20 pounds. This pressure should be maintained at all times. For most men the tank is most effectively carried on the left shoulder at an angle of about 35° with the body. The shut-off is operated by the right hand. The oil is rather caustic, and will blister the skin if it comes in contact with it to any great extent. For this reason clothing should be worn that will give the greatest protection, and the spilling of oil on the tank should be avoided.

Before oil is sprayed on an infested tree, the oil and pressure should be checked to determine whether it is sufficient to complete the application. A stream of oil is directed against all parts of the trunk, care being taken to distribute it evenly and to avoid spattering. As the bark is thicker at the base of the tree, care must be taken to soak this section thoroughly. Since it is desired to create an intense heat and burn out the top if possible, advantage should be taken of any dead limbs or witches' brooms which lie close to the trunk, and spray oil upon them, which will materially increase the intensity of the fire. When there is considerable wind, it is necessary to give a thorough soaking to the side of the trunk towards the wind, and oftentimes it is better to use but little or no oil on the side away from the wind, except at the base and after the fire has been started, as the wind will blow the flame around this side. If there are two or more trees standing close together, they should all be prepared for treatment before the fire is started. Group burning gives increased heat and results in better treatment. After the tree has been soaked with oil, and proper pressure restored to the tank, a lighted match is thrown on the oil at the base. As the flame starts, additional oil is sprayed on to build up the volume of flame, and this is carried up the tree. A good flame developed at first is far more effective than after the first application of oil has been partially burned off.

With large trees, or where the use of extensions are necessary, the burners should work in pairs, one with and one without extensions. This permits the tank without extensions to oil the base of the tree up to 20 feet while the other burner cares for the upper portion. When the

fire is started, the tank with extensions is used to build up an intense heat at the maximum point of oiling, which often results in the fire crowning out through the top of the tree.

When the bark is cold, or immediately following storms, a greater amount of oil is necessary than when the bark is dry and warm. Green trees with new attecks also require more oil than those which are considerably dried out. Extensions should always be used when there is any doubt as to the ability to reach the height of infestation without them. It is more effective to use them and burn out the tree at one burning than to go back for a second attempt after the base has been burned. Sometimes poles or brush placed against the base of the tree will aid in generating heat, and force the flames to a greater height. As it is impossible to determine the height of the infestation of large standing trees, if the bark is not thoroughly scorched up to a six- or eight-inch top diameter, the tree must be felled for subsequent treatment if all insects are to be destroyed. With such cases the judgment of the crew foreman must be depended upon. Cold or high wind greatly retard the effectiveness of burning, and at times it may be advisable to institute evening or night burning when such interference becomes serious. The same action may be necessary towards the end of the season when the danger from fire becomes acute. Early morning burning can often be safely employed in times of dangerous fire weather.

Care and attention to the many details of this method will result in an increased efficiency. As there are many details which can not be covered in a lesson of this character, a great deal depends upon supervision and individual effort of burners to produce effective work with

a minimum expenditure of time and oil. The following points contribute towards the efficiency of burning:

Avoid: - Wasting oil

Useless treatment of noninfested portions of trees

Skipping infested sections of the bole

Insufficient heat at the base

Missing infested trees

Lighting before tree is properly prepared

Do: - Reach all infested sections of the tree.

Use extensions whenever necessary.

Make sure there is sufficient oil and pressure in tank to build up heat before lighting.

Build up a quick heat.

Make sure the base of tree is properly treated.

Treat all trees to a six- or eight-inch top diameter or fell them for subsequent burning.

When this burning-standing method of treatment is used, spotting and treating are usually performed in one operation. A short pack string, with spray tanks, felling tools, and an extra supply of oil, follows the spotting crew, and as infested trees are located the equipment is brought up and the trees treated. The crew operates as a spotting crew with the exception that the trees are not marked nor is a map constructed. The crew foremen keep a record of the number of trees treated. Over extremely rough terrain, where pack horses can not travel, tanks are carried by the spotters. This should be avoided whenever possible, as a man can not look for bug trees when traveling over a rough country burdened with a 3-gallon tank of oil.

The cost of this method, if computed on a tree basis, is dependent upon the severity of the infestation, and will vary with such factors as the cost of transporting oil, nature of terrain being covered, and character of labor available. Though the initial cost of the oil is not great, the transportation from railhead and distribution in the field are factors to be considered. Though the amount of oil required for each tree is dependent upon diameters and height of infestation, it will be found that for the usual type of lodgepole infestation approximately 3/4 of a gallon will be required for a thorough treatment.

Peeling of infested trees successfully destroys insect broods beneath the bark if the work is done while the insects are in a larval or first-pupal stage. However, the bark is very difficult to remove, which makes the operation so expensive that it should never be employed when the use of fire is possible.

Administration of Control Projects

Control projects should not be hastily instituted. All possible information should be secured before the advisability of control can be properly determined. There are many instances where projects have been launched upon inadequate data, only to find that the effort had been wasted. Data should be secured from all areas adjacent to the one in question in order to determine the exact status of the infestation, which is essential in determining the advisability of control.

No project should be instituted without adequate trained overhead. The efficiency of spotting and treating is a direct reflection upon the

the character of the supervision which has been given. Insufficient supervision is false economy.

MOST IMPORTANT BARK-BEETLE ENEMIES OF LODGEPOLE PINE

Though, as stated, there are a rather large number of bark beetles which attack lodgepole pine, there are only a few which can be considered as being of economic importance. A brief description of these will follow:

Mountain Pine Beetle (Dendroctonus monticolae Hopk.)

The mountain pine beetle is found throughout the western and northern Rocky Mountain states, and is considered as one of the most destructive forest insects in the western states. It attacks and kills all species of pine, and sometimes Engelmann spruce, from small to large diameters. Though during endemic infestation there may be a tendency to select the weaker, slower-growing trees for attack, no such selections are apparent during epidemic conditions.

Adults of the mountain pine beetle are rather stout, black, cylindrical beetles varying from .15 to .25 of an inch in length. The female beetle constructs a long, perpendicular egg gallery directly beneath the bark, which slightly grooves the wood. At the bottom of this gallery there is a slight crook, or bend, an inch or two in length. The perpendicular portion of the gallery, which varies in length from 12 to 36 inches, nearly always follows the grain of the wood. During the construction of this gallery, eggs are deposited in small niches along the sides, which hatch in a few days. The small white grubs, or larvae, excavate short feeding tunnels at right angles to the egg gallery, which

vary in length and are exposed on the inner surface of the bark. When full-grown, the larvae construct small pupal cells at the end of the larval mines, in which they transform first to pupae and then new adults. The new adults may bore away the intervening bark between pupal cells and congregate beneath the bark prior to emergence, or individual emergence holes may be constructed direct from pupal cells. Two or more insects often use the same emergence hole, and emerging beetles often take advantage of cracks in the bark or holes resulting from woodpecker work.

Normally there is but one generation of this insect in lodgepole pine each year. The general attack period extends from the last of July until well into September. The late attacks are explained by the emergence of parent adults some 30 days after attack, and subsequent attack of a second tree. The brood usually pass the winter as larvae, and reach maturity by the following July.

Black Hills Beetle (Dendroctonus pseudotsugae Hopk.)

The Black Hills beetle, equal in economic importance to the mountain pine beetle, is found from the Black Hills of South Dakota and western Montana southward through eastern Wyoming, Colorado, Utah, Arizona, and New Mexico. It attacks and kills nearly all pines within its range, and occasionally spruce when associated with infested pine. Though it has a decided preference for healthy, middle-aged, and mature trees, it will attack and kill trees from four inches in diameter to those of the largest size.

The adult Black Hills beetle is a stout, black, cylindrical beetle varying from .18 to .28 of an inch in length. The work of this beetle is very similar to that of the mountain pine beetle, and can hardly be distinguished from it. In fact, the work of the two insects is so similar that a different description can hardly be given. The seasonal histories of the two species are practically the same, though it is not definitely known if the parent adults emerge and make a second attack.

A rather fixed habit of the Black Hills beetle is to concentrate in force and attack a number of trees in a group. These groups may vary from two or three to as many as 350 or more, the number being a good indication of the severity of the infestation.

Lodgepole Pine Beetle (Dendroctonus murrayanae Hopk.)

The lodgepole pine beetle, found in eastern Washington, Idaho, Montana, Wyoming, and Colorado, is of no great economic importance, though it does attack and destroy large, overmature lodgepole pine. The adult insects are stout, cylindrical bark beetles varying from .21 to .26 of an inch in length. The wing covers, or elytra, are of a distinct reddish color, with the prothorax and head dark brown or black.

The attacking adults bore through the bark on the lower bole, and construct short egg galleries varying from five to twelve inches or more in length directly between the bark and wood. Eggs deposited along one side of these galleries are separated from each other by boring dust. The larvae feed away from the egg gallery, keeping

together in a common excavation, or brood chamber, there being no separate, or individual, larval mines whatever. Transformation to new adults takes place in cells constructed in the uneaten part of the inner bark or in cocoonlike structures composed of excrement in the brood chamber. Though the seasonal history of this insect is not thoroughly known, it is assumed that there is but one generation a year.

Attacks of this insect are easily determined by the large pitch tubes an inch or more in diameter which form at the entrance holes. There may be from five or six to as many as twenty five or more of these attacks around the base of each tree, but they seldom extend to a height of more than four or five feet. A tree may be attacked by these beetles for three or four successive years before its resistance is sufficiently lowered to attract an attack of other bark beetles, usually secondary, in the upper portion of the bole. In some instances trees are killed by initial attacks of lodgepole pine beetles, while in other cases they may abandon living trees. The attacks of this beetle can be considered as primary, as it is the initial injury which leaves the tree in a weakened condition attractive to secondary insects. When large, overmature lodgepole pine are left during timber sales or tie operations, a large percent of them are often destroyed by lodgepole pine beetles, which develop in large numbers within freshly cut stumps. Fortunately, such outbreaks have always died down at the close of the operation.

Oregon Pine Engraver (Ips oregoni Eich.)

The Oregon pine engraver is at times an economically important enemy of lodgepole pine, and is found throughout the western United

States, where it attacks ponderosa pine, lodgepole pine, and perhaps other species. The adults are small, reddish to brownish black, cylindrical bark beetles, .16 to .20 or an inch in length, with four spinelike teeth along the margin of the elytral declivity. It prefers tops and large limbs of trees killed by Dendroctonus beetles, weakened or dying trees, windfalls, green logs, and all slash as host material, but under certain conditions will often attack healthy trees. Abnormal accumulation of such favorable host material provides optimum conditions for rapid and successful development of these secondary beetles, which often become primary in their attacks when more favorable material is exhausted.

An attack is made by male beetles constructing nuptial chambers beneath the bark, which when complete are used by females as starting points for their individual egg galleries. These galleries, which vary in length from five to ten inches, are always free from boring dust. The number of females using each one of these chambers varies from one to as many as seven, with an average of three or four. Though the individual egg galleries radiate from the central chamber, as soon as other channels are cleared they turn up or down the tree, usually following the grain of the wood.

Eggs are laid in small niches along the individual galleries, which hatch in a very few days. There are from two to four generations of this beetle each year, depending upon length of season. Parent adults emerge and make a second and sometimes third attack, which results in a confused overlapping of broods.

Other Bark Beetles

There are other species of Ips as well as other genera which under abnormal conditions are found attacking lodgepole pine. These outbreaks are usually short-lived, and control measures are seldom considered as being necessary.